

Gender Differences in Mathematical Ability

An Honors Thesis (HONRS 499)

by

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Abstract

The purpose of this study was to explore gender differences in mathematics. The first part of this study was a literature review and the second part was an empirical study. The literature review began with an overview of the work of Maccoby and Jacklin (1974). Then a review of recent research was done to compare and contrast current ideas of gender differences in mathematics with those of Maccoby and Jacklin. Finally, suggestions were made to alter the socialization of students to reduce the gender differences. The second part of the study included the collecting and analyzing of data. Mathematics and English grades and Scholastic Aptitude Test (SAT) scores, along with the students' age and gender, were recorded. From this information, questions were answered dealing with mathematical gender differences.

Gender Differences in Mathematical Ability:

A Literature Review

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Gender Differences in Mathematical Ability:

A Literature Review

Introduction

In their book, The Psychology of Sex Differences, Maccoby and Jacklin (1974) claimed that there were four main gender differences: a) girls have greater verbal ability than boys, b) boys excel in visual-spatial ability, c) boys excel in mathematical ability, and d) boys are more aggressive than girls. According to their review of the literature, verbal differences included differences in reading, writing and vocabulary. Results of the research on verbal ability showed slight gender differences from preschool to early adolescence. Differences became more evident at approximately eleven years of age with girls appearing to be superior to boys. Visual-spatial ability, a concept which is hard to define, involves an ability to recall, recognize, and transform symbols or patterns. The male superiority for visual-spatial ability was not found in children, however, it was evident in adolescents and adults. Computation and reasoning were both a part of mathematical ability. Gender differences were very slight in mathematical ability until approximately age twelve. At this age, boys' abilities increased at a faster rate than did girls'.

Because the solution of a mathematical problem could require both verbal ability and visual-spatial ability, the degree of male superiority over females differed from test to test. Both physical and verbal aggression were seen stronger in boys than girls, beginning as early as two years old. Aggression seemed to decline in both males and females with age, remaining strongest in males at all times. Maccoby and Jacklin believed that all these differences were the result of a) genetic factors, b) shaping of boy-like behavior and girl-like behavior by parents and other socialization agents, and c) children's spontaneous learning appropriate for their own gender through imitation. Since the publishing of this book, much research has been done to expand and verify the findings of Maccoby and Jacklin. The purpose of this paper was to review the research on gender differences in mathematical ability.

In the review of the literature, Maccoby and Jacklin (1974) reported that there were few gender differences in mathematics until adolescence. The gender differences became more apparent between nine and thirteen years of age when boys begin to excel over girls. However, the age at which differences appeared varied depending on the measure used. Some research suggested that gender differences do not appear until adolescence because boys have been socialized over time to have a greater

interest in the mathematics and science fields than have girls. Boys also tend to take more mathematics and science classes than girls when given the chance. However, Project Talent (Flanagan et al., 1961; c.f. Maccoby & Jacklin, 1974), a research project, showed that even when girls and boys had the same background, boys still did better than girls in quantitative abilities. In addition, Harvard Project Physics (Walberg, 1969) showed that on a mathematics and physics test, even though boys did better than girls on the visual-spatial skills, girls did better than boys on the verbal test items. This study showed that visual-spatial ability and verbal ability may be responsible for differences in science and it is believed that a similar situation exists in mathematics.

Mathematical ability is not considered a unitary factor. There are many ways to approach and solve mathematical problems. Therefore, it is important to understand different mathematical styles before gender differences in mathematics can be understood. In considering different mathematical problems, numbers can be represented as symbols or words; a problem can appear as an equation, a word problem, or a diagram. Solving may involve manipulating mathematical symbols or verbal symbols. Thus it is easy to see how visual-spatial abilities and verbal abilities may be strongly correlated with mathematical abilities

(Flanagan et al., 1961; c.f. Maccoby & Jacklin, 1974). It is not clear, however, whether these differences are the result of environmental factors or of heredity.

Vandenberg (1968; c.f. Maccoby & Jacklin, 1974) stated that both verbal ability and visual-spatial ability are strongly linked to heredity with verbal ability being influenced greater by environmental factors than visual-spatial ability. It is believed that genetics plays an important role in the development of visual-spatial abilities--the gender difference favoring boys, which begins approximately at age six and increases with age. Visual-spatial ability is believed to have a genetic sex linkage to the X-chromosome (see Maccoby & Jacklin, 1974, for a review). Therefore spatial ability is more likely to be expressed in males than in females in a ratio of two-to-one. Verbal ability is also believed to be hereditary, but not to the degree of visual-spatial ability, and there is no evidence that verbal ability is sex-linked.

In addition to genetic factors, social factors play a part in gender differences in intelligence. Maccoby (1966) stated that there are four personality differences between males and females which influence intellectual gender differences. First, boys are more independent, and for both males and females, independence is directly related to positive

performance, particularly in visual-spatial ability. Second, females tend to use more internal serial processing which may be positively related to verbal skills. Third, males have a higher activity level involving restructuring or breaking set which may facilitate visual-spatial skills. The last difference deals with aggression and impulsion. Boys tend to be over impulsive and too aggressive, as a result they do not take time to fully understand a topic. Girls, on the other hand, are too timid. They are dominated by the boys and are too scared to actively take part in activities or ask questions.

Parents also play a large role in their children's gender roles. Children spend their early years at home where the gender role is first defined. One way in which this is defined is in play. Parents buy gender-typed toys for their children, such as dolls for girls and trucks for boys. Likewise, it is considered wrong for boys to act feminine, while it is not considered wrong for girls to act like tomboys. Parents tend to discourage gender-inappropriate behavior in boys more than girls and this was seen especially with fathers and their sons (Lansky, 1967). As children grow, parents also tend to have a greater desire for their sons to go to college than for their daughters. Boys are believed to receive an advantage in visual-spatial ability and some believe girls receive an

advantage in verbal ability because of early interaction. It is assumed that girls have a greater verbal ability because they receive more verbal stimulation or reinforcement beginning as an infant. Some research shows that educated mothers have daughters with a higher verbal ability than sons. However, no difference was found with mothers who had less education. There is no positive relationship between the amount of verbal stimulation given to sons or daughters and their verbal ability (see Maccoby & Jacklin, 1974, for a review).

Maccoby and Jacklin (1974) stated six hypotheses concerning gender differences in achievement motivation. The hypotheses are as follows:

- 1) Males have a greater need for achievement and are more oriented toward achievement for its own sake.
- 2) Males show greater task involvement and persistence.
- 3) Males show more curiosity, and engage in more exploratory behavior.
- 4) Females are motivated to achieve primarily in areas related to interpersonal relations whereas males strive to achieve in non-personal-orientated areas, including intellectual endeavors.
- 5) Female efforts to achieve are primarily motivated by the desire to please others, so that regardless of the area of achievement they care

primarily about praise and approval for their performance, whereas males are more motivated by the intrinsic interest of the task.

6) Females have low self-confidence about many tasks. This is sometimes thought to be part of a generalized lack of self-esteem.

The intent of Maccoby and Jacklin's (1974) literature review was to determine which beliefs concerning gender differences are myths and which are supported by evidence. Results showed that boys definitely excelled in mathematical abilities. However, the extent and the reasons still remain a mystery. This is a mystery which researchers are still trying to solve. Since the publishing of Maccoby and Jacklin's book, research on the mathematics controversy has not come to a halt. On the contrary, researchers are still attempting to solve the baffling question of how and why this mathematical difference exists. The remainder of this paper examines current research which may either support or alter the theories of Maccoby and Jacklin.

Nature versus Nurture

There is still much controversy on whether intelligence, including mathematical ability, is the result of environmental influences or genetic influences. However, little controversy is created concerning the existence of a gender difference related to mathematics ability found in

the daily activities of men and women in modern Western culture. Most of the students studying to be elementary school teachers, nurses, and secretaries in coed colleges are females, whereas the mathematics, science, and engineering majors are males. Mothers are almost always the primary homemakers when this role is filled by one parent. Many occupations appear to be single gender occupations, while few neutral occupations come to mind (Halpern, 1992). The question of whether these differences are because of biological or environmental influences, nature or nurture, although investigated intensely for years, still remains unanswered.

Few modern psychologists believe in the "either/or" theory. Nature and nurture are expressed in combination. Diamon (1988) did research concerning the effects of different environments on the morphology of the brain using rats. Results showed the brain differed in cortical thickness and weight, the branching of the neurons, number of nourishing tissues, and cell size depending on whether the rats lived in a rich or poor environment. Aging in the rats also brought about brain differences depending on environmental changes. Thus, it would be difficult to determine differences in male and female brains, when environment creates fluctuations.

To study nature versus nurture, it is important to study people with genetic make-up which is as similar as possible. Parent-offspring data has the disadvantage of having subjects at different ages. Siblings do not have this problem to the same degree, and, as a result, there is a higher correlation between the genetic makeup of siblings than between parent-offspring. Only twins have the obvious advantage of being the same age (Tellegen, Lykken, Bouchard, Wilcox, Segal, & Rich, 1988). There are two types of twins: monozygotic (identical), who share 100 percent of their genes, and dizygotic (fraternal), who share approximately 50 percent of their genes (Rushton, Pulkert, Neale, Nias, & Eysenck, 1986). If genetics have a greater influence than the environment, monozygotic twins should be more similar on a particular characteristic than dizygotic twins (Scarr, Webber, Weinberg, & Wittig, 1981).

Monozygotic and dizygotic twins, some of whom were reared together and some of whom were reared apart, were studied to try to separate genetic influences from environmental influences. The studies were performed by comparing, contrasting, and measuring the twins physiology, behavior and intellectual levels. Most results showed that both genetics and environment contribute equally (Rushton et al., 1986).

When discussing education topics in reference to nature versus

nurture, the intelligence quotient (IQ) levels become an important question. Bouchard and his colleagues (Bouchard, Lykken, McGue, Segal, & Tellegan, 1990) concluded that, assuming no environmental similarities, genetic factors account for approximately seventy percent of the differences in IQ level. It was also found that genetic influence on cognitive ability increases with age. They determined that environmental influences may affect the rate of cognitive development, yet genetics determine the ultimate level of achievement. Thomas Bouchard stated in an interview with Thomas Shovholt (1990) that instead of this being a nature versus nurture issue, it is now a nature and nurture issue. The scientific question is no longer how genetic factors affect traits, but how genetic and environmental factors combine and interact to affect traits (Bouchard & McGue, 1990). Bouchard and his colleagues (1990) believed it is especially important in education programs to watch children closely and monitor their behavior, attitudes, and skills to help to provide an environment which will encourage the children to develop these positively. Often, genetic traits are more fully expressed in a compatible environment (Shovholt, 1990).

Genetic Theory

Camilla Benbow has been a leader in the search for a genetic reason

for the mathematics difference between boys and girls. Although criticized for the publishing of her results, at what some felt to be a premature state, Benbow (1990) believed it was important for girls to realize that genetically they may not be as intelligent as boys. She emphasized that this was not to discourage girls, but to make them aware of their situation. Benbow's collaboration with Julian Stanley of Johns Hopkins University (Benbow & Stanley, 1980, 1983) also concluded that boys have a genetically higher mathematical ability than girls. The evidence they had was so striking, that it was hard for them to believe that the difference was from socialization alone.

The testing at Johns Hopkins began in 1972. From 1972 to 1979, six different groups of students were tested by taking the Standardized Achievement Test (SAT). These students were seventh or eighth graders who had scored in the upper two to five percent of the standardized mathematical tests. In 1980, the seventh and eighth graders had to have scored in approximately the 97th percentile of standardized mathematics achievement tests in order to participate in the testing at Johns Hopkins. Each year girls' and boys' results were the same on the verbal section of the SAT, whereas the boys did extremely better on the mathematical section of the test. In fact, twice as many boys as girls scored over 500

on the mathematics section.

Benbow and Stanley (1980, 1983) began their testing to find gifted children and were surprised when they discovered the gender difference. In replicating the tests, the gender differences reappeared. In trying to find an explanation for the differences in math scores, they thought perhaps they had failed to reach girls with high math levels or had used girls who had taken fewer mathematics classes. However, the girls who took the test said they all enjoyed mathematics and there was no evidence of mathematical anxiety. Further investigation showed that when the number of mathematical classes was accounted for, the difference still remained. Still wondering if social factors do play some part, the researchers at Johns Hopkins are checking the backgrounds of the students tested. Questions are being asked such as the type of toys played with and parental influence and desires. They also want to find out whether or not the boys and girls differ in test-taking strategies (Kolata, 1980).

In addition to testing, Johns Hopkins offers accelerated mathematical classes for qualifying boys and girls. Fewer girls than boys qualify for these classes and even fewer girls are willing to participate. In addition, of the girls who do participate, many tend to drop out. When questioned, it was found that girls did not wish to participate for fear of

being called different by other friends. The girls also thought mathematical classes were boring and that the boys were "little creeps." This led the researchers at Johns Hopkins to believe that perhaps it was social factors which prevented genetic factors from being fully expressed. So an all-girl accelerated mathematics class taught by women was created. At first, the results were encouraging. More girls were willing to participate and fewer dropped out. However, in the long run, the results of the class were disappointing. When the girls attended college, their mathematics grades and the number of mathematics classes they were taking were no better than the control group of girls who were not invited to join the all-girl class. Some believed the reason for this was because girls needed to be constantly encouraged to challenge their mathematical ability (Koloata, 1980).

Despite the research, theories, and hypotheses, there is no solid proof that genetic reasoning can account for gender differences in mathematics. Premature speculation can be hazardous to current research and beliefs. Benbow (1990) believes that women would be better off accepting their differences. She believes girls would do better in the mathematical field if they realized their disadvantages and strived to reach their highest potential possible, instead of blaming failure on social

factors. Kolata (1980), on the other hand, discusses the arguments of researchers who disagree with Benbow. Mary Gray, a mathematician at American University in Washington, D.C., who is active in the Association for Women in Mathematics, says that there is too little known about mathematical reasoning to state that these differences are based on genetic differences alone. Elizabeth Fennema, a member of the education department at the University of Wisconsin, says she feels the researchers at Johns Hopkins are being very dangerous by drawing genetic conclusions. She does not believe that their data can create any explanation for why women are not equal in the mathematics field in college. Research is still too contradictory to draw a valid conclusion.

One reason mathematical ability is so difficult to localize is that the bases of some mathematical problems are verbal in nature, such as word problems, while others are spatially related, such as in geometry. While the idea of mathematics being related to genetics is controversial, there is strong support that visual-spatial ability is genetically influenced. Since visual-spatial ability is closely related to mathematical ability, the genetic basis for visual-spatial ability may indirectly effect mathematical ability. The exact genetic basis for visual-spatial ability is unknown, but there is support for an X-linked trait,

hormones, or hemispheric specialization. It is still unknown if these traits are independent or dependent, and if dependent, to what extent they rely on one another.

For over thirty years it had been suggested that visual-spatial ability may be because of an X-linked trait (Stanford, 1961). If it is X-linked, then a boy's visual-spatial ability should be related to his mother's visual-spatial ability, but not his father's, since a son will receive an X chromosome only from the mother. These results were supported by some studies, but not by all. Hoben Thomas and Robert Kail (1991) found support for the X-linked hypothesis, but the results were not precise as to what may influence the X-linked gene. Prenatal hormones, hormone levels at puberty, or hemispheric specialization may all effect the X-linked hypothesis, however, the research did not distinguish among these three. Thus, the X-linked inheritance may not directly affect visual-spatial ability, but may affect one of these characteristics which may in turn affect the visual-spatial ability.

It was stated earlier that differences in mathematical ability are not evident until eleven to thirteen years of age. This is also the approximate age at which puberty begins. This suggests that prenatal hormones or puberty may play a part in cognitive development. Hier and

Crowley (1982) have stated a theory that the amount of androgens at puberty may effect visual-spatial ability. They studied 19 men who had an androgen deficiency at puberty and found that all 19 men had lower visual-spatial ability as compared to men with normal levels of androgen. They also noted that there was a direct relationship between the degree of visual-spatial ability impairment and the degree of androgen deficiency. Those whose androgen level was closest to normal showed the least impairment while those with the greatest deficiency showed the greatest impairment. It was also noted that these men showed no verbal differences.

Hier and Crowley (1982) believed that the androgen level at puberty was crucial for the development of visual-spatial ability. They also believed if a person failed to develop their visual-spatial ability because of androgen levels at puberty, this disability cannot be corrected. However, it must be remembered that Hier and Crowley used a small sample of men to support their conclusions. And if their conclusion was correct, the levels of androgen which would affect the visual-spatial ability was unknown (Halpern, 1992).

Just as there is support for the relationship between puberty and visual-spatial ability, others have found no support for the theory. Two

different literature reviews found that the relationship between puberty and visual-spatial ability was small, while two other reports (see Halpern, 1992, for a review) have found no support for this relationship.

Sanders and Ross-Field (1986) presented another theory, stating that homosexuality might be affected by the same prenatal hormones that are involved with cognitive sex differences. Using several different tests of visual spatial ability and replicating the testing three times, the results verified that homosexual males have a level of visual spatial ability similar to that of women. Both the homosexuals and the women scored significantly lower than heterosexual males in visual-spatial ability. They believed that there was a connection between sexual orientation, cognitive ability, brain organization, and the level of testosterone at birth. These results have been replicated and verified by other researchers. However, when similar testing was done using lesbians and heterosexual women, it was not found that lesbians were better at visual-spatial abilities than the heterosexual women (Gladue, Betty, Larson, & Staton, 1990).

Geschwind and Galaburda (1987; c.f. Halpern, 1992) believed that prenatal sex hormones which direct sexual differentiation of the fetus, also may affect the central nervous system. Their theory stated that high

levels of testosterone slow the growth of neurons in the left hemisphere of the brain; thus, the right hemisphere has greater control. Further, the right hemisphere of the brain is the source of high visual-spatial ability (Halpern, 1992). This research is in agreement with studies which have attempted to find a relationship between the rate of maturation and the levels of cognitive ability. Girls tend to mature physiologically quicker than boys throughout puberty (Smolak, 1986). Research results of Waber (1976, 1977) showed that, regardless of gender, those who matured later had higher visual-spatial ability. Therefore, in general, boys would tend to have greater visual-spatial ability.

For every researcher who has found evidence for a genetic theory, there is a researcher who has contradictory evidence. Also, those researchers who have found evidence for the genetic theory have hypotheses concerning the genetic source, however, no one has been able to prove precisely what genetic concept causes greater mathematical ability. It should also be noted that many researchers who support the genetic theory tend to ignore social concepts in research. For example, Camilla Benbow began her testing at Johns Hopkins in 1972. As a result of her testing, she took a public stand in favor of the genetic theory. Now she is going back to analyze how socialization may have affected her

results. It will be interesting to see if she will support the genetic theory as strongly as she did once she has her results. Research has shown that it is difficult to test the genetic theory because each person tested has been affected socially in different ways. Thus it is probably not possible to consider the genetic factor alone.

Socialization Theory

In deciding how socialization plays a part in the gender differences of mathematics, Halpern (1992) created a list of six hypotheses:

1. Females maintain more negative attitudes toward mathematics.
2. Females perceive mathematics to be less important for career goals than males do.
3. Females have less confidence in their ability to learn mathematics.
4. Mathematics is a male-stereotyped cognitive domain.
5. Females receive less encouragement and support for studying advanced mathematics.
6. Females take fewer mathematics courses than males; therefore, they score lower on tests of mathematical reasoning ability.

These six hypotheses will serve as a guideline for the review of the literature on the socialization influences on mathematical ability.

1. Females maintain more negative attitudes toward mathematics.

Failure on a mathematics test is usually attributed to lack of ability by girls. Girls are also more likely than boys to claim that the reason they did poorly on a mathematics test was because mathematics, in general, was difficult. This implies the girls have a negative attitude towards their mathematical ability (Stipek, 1984). The reason for females' negative attitude toward mathematics is related to hypothesis #3 and will be developed further there.

2. Females perceive mathematics to be less important for career goals than do males.

Females experience great conflict between career and parental goals. Although men remain employed full-time with the addition of a family, women expect to be employed part-time or not at all (Sherman, 1983). Because mothering is considered an extremely important role, females tend to choose careers which will not interfere with motherhood. Careers involving mathematics are considered full-time careers and may be threatening to motherhood (Luchins & Luchins, 1980). The idea of future conflicts with motherhood may keep women from pursuing careers which involve mathematics. Likewise, women with high mathematical ability who fear conflicts with motherhood feel that the usefulness of higher

mathematical courses is not as great as motherhood itself (Kimball, 1989).

3. Females have less confidence in their ability to learn mathematics.

This is an ironic statement because, even though males score higher on the mathematics portion of the SAT, females have been found to have a higher GPA in mathematics than males (Miller & Crouch, 1991). Their confidence in mathematics may be lower, however, their ability seems to be higher.

Because females usually perform better than males in mathematics, it would be assumed they would have high confidence. One possible reason for low confidence is that females, more than males, attribute success to luck rather than ability (see Stipek, 1984, for a review). Thus, females are denying themselves the self-esteem they deserve and the security they would have for future mathematics classes (Stipek, 1984). Stipek (1984) also found that if girls did do poorly on a mathematics test, they would attribute the failure to lack of ability more often than boys. Girls were also more likely to state that "mathematics is hard" as the reason for a poor test.

Within the same group of students, Stipek (1984) also noted spelling

test grades in which boys did poorer than girls. The boys reasoning for poor performance was that they were in a bad mood at the time of the testing. This excuse did not threaten their self-esteem as the girls' reasoning for mathematics failure had. Because of this, the boys did not expect to do poorly on the next test, while the girls had lower expectations following a poor test.

The difference between elementary age females and junior high girls as found by Stipek and Gralinski (1991) should also be noted. Although both the younger and the older girls attributed failure to low ability, it only had a negative effect for the older girls. The younger girls believed anything could be accomplished if they tried hard enough. They also believed failure could be overcome if they tried harder. Unfortunately, these optimistic ideas disappeared by the junior high age.

Although females have been found to have low self-esteem in a number of gender-related issues, it was found to be most consistent in mathematics (see Stipek & Gralinski, 1991 for a review). It is believed that these feelings play a large part in the limited numbers of females in mathematics.

4. Mathematics is a male-stereotyped cognitive domain.

Martha Smith, a professor of mathematics, described the negative

stereotype associated with female mathematicians: "Many people on hearing the words 'female mathematician' conjure up an image of a six-foot, gray haired, tweed suited oxford clad woman...This image, of course, doesn't attract the young woman who is continually being bombarded with messages, direct and indirect, to be beautiful, 'feminine', and catch a man." (from Ernest, 1976, pg 14; c.f. Halpern, 1992). Few women would choose to identify with this stereotype even if they were mathematically gifted.

One of the greatest sources of stereotyping is the media, particularly television. This is a sad concept when we realize that by the age four, most children have watched between 2,000 and 3,000 hours of television (Stewart, 1976). Calvert and Huston (1987; c.f. Halpern, 1992) stated that most television males are represented as dominating, aggressive, hard workers with goals. Women are mostly represented as passive and defiant housewives. In an analysis of 300 television commercials, Hoyenga and Hoyenga (1979; c.f. Halpern, 1992) reported that approximately 90% of the time females were seen in the following roles: caring for babies, washing clothes and dishes, shopping, and cooking; while men were seen 90% of the time in the following roles: farmer, businessman, soldier, service station attendant, and athlete.

Television also relays the message that marriage and parenthood are more important to females than males. Kimball (1989) believes one reason women are so reluctant to go into a mathematical field is because of a struggle between career and parental goals. Whereas a woman expects to be employed part-time or not at all when children are young, men of young children do not expect to have their careers affected. Most college women value their future roles as mothers very highly and occupations which may conflict with motherhood are those in the science and mathematics fields. This is a valid concern since female mathematicians report greater conflicts between career and family than do male mathematicians (Luchins & Luchins, 1980). Although there have been some changes in television in the past 15 years, stereotyping still exists. Bretl and Cantor (1988) have found that although men and women may appear equally often in prime-time commercials, women are still found most often in a domestic setting.

It is believed that children learn about gender roles from the males and females they observe, as supported by the Social Modeling Theory. This theory also states that children are more likely to imitate models of their own gender. Support for this theory has been found in different experiments (see Halpern, 1992, for review).

With the idea of the Social Modeling Theory in mind, it is sad to state the findings of Joanne Rossi Becker (1981). Becker chose to study ten different geometry classes consisting mostly of ninth and tenth graders. Geometry classes were chosen because it seems that the greatest percentage of females drop out of mathematics classes after taking geometry. Becker found that the traditional view of male dominance in mathematics was reinforced by the physical setting of the classrooms. The ratio of male mathematics teachers to female mathematics teachers is 2:1. The geometry textbooks used mostly men in the essays on history and careers. Although teachers may have no control of the textbooks, not one teacher tried to counteract the gender bias by using additional materials. Also posters of mathematics used as displays included men as their models. One particular poster had 13 pictures of different forms of measurement, all of which included only men. The teachers also tended to use male pronouns in examples and in referring to people who work in the mathematics field.

5. Females receive less encouragement and support for studying advanced mathematics.

Two important sources of encouragement and support for students are parents and teachers. Parents are the primary socializing agents for

children. Parents' encouragement and support for their children begin at birth and, unfortunately, so does stereotyping. One major way in which parents create this stereotyping is through the selection of toys (Etaugh, 1983). Girls receive dolls while boys receive trucks and toy guns. By age two to three, children know which toys are "gender-appropriate" for them. As children get older, parents buy more science-related toys (such as microscopes and chemistry sets) for their sons than for their daughters. Graham and Birns (1979) stated that boys are more likely to receive mathematical toys and games and receive more individual instruction from their parents in mathematics than girls.

Becker (1981) stated that teachers had expressed to her that parents expect their sons to take higher mathematical courses because it will be essential to their futures. However, parents did not feel that this was true for their daughters. Entwisle and Baker (1983) also noted that parents play a strong role in expectation and performance of a student's mathematical ability, especially in the middle-class family.

Teachers are also a source of encouragement and support for students, and because schools are the only institution in society designed specifically for educating children, it is unfortunate that it is also a source of stereotyping. In the Sadker and Sadker (1985) study of 100

fourth-, sixth-, and eighth-grade classes, all the teachers they observed reported that they treated girls and boys equally. However, observations showed that gender role stereotyping was present. Teachers, in most cases, were not even aware that they were influenced by or were relaying gender role stereotypes.

Encouragement within the classroom has a wide range of diversity (Becker, 1981). Males receive 70 percent of positive reinforcement in the classroom while females receive only 30 percent. Negative comments are given less often than positive comments. But, of the negative comments, girls receive these almost nine times out of every ten times. Of the examples used in the geometry classrooms, teachers often refer to objects from shop class, with few examples with which females can relate. If teachers wander around the classroom during study time to help students individually, the teachers spend more time with males than with females. Although touching is infrequent (i.e. pat on the shoulder), it is done to male students only by both male and female teachers.

Within the classroom, boys tend to dominate classroom discussion. Sadker and Sadker (1985) found that, because girls sat patiently with their hands raised, and boys tended to speak out openly, boys were eight times more likely to answer questions than were girls. Becker (1981)

found similar results. The teachers she worked with stated that females were serious students who were more conscientious, quieter, and more self-motivated. The teachers also felt that the girls received better grades in mathematics because they handed in complete assignments on time more often than did boys. It was believed that males needed more attention to stimulate them and to keep them on task. One teacher even commented that it was easy to ignore females who worked quietly without extra attention.

The relationship between the students and teachers expectations might be related to the idea of the self-fulfilling prophecy. This states that teachers' expectations for students' performance can determine the students' performance (Rosenthal & Jacobson, 1968). Likewise, Cooper (1979) believes that teacher expectations maintain differential performance rather than cause it.

6. Females take fewer mathematics courses than males; therefore, they score lower on tests of mathematical reasoning ability.

Even though mathematics is considered an important high school subject -- important for many future educational and job opportunities -- few students take advantage of higher level mathematics classes. This is particularly true of females. Among students taking the College Board

Exam, 73% of the males had taken seven or more semesters of mathematics while only 57% of the females had taken this amount of mathematics (Sherman, 1983). Even women with high mathematical abilities drop out of mathematics and science classes at a greater rate than men, beginning when classes are optional at the high school, undergraduate, and graduate levels (MacDonald, 1980). However, there have been studies in which boys and girls have had the same number of mathematics classes and boys have still received higher scores (see Halpern, 1992, for a review).

Becker (1981) chose to use geometry in her studies because, following geometry, a significant number of females do not continue with higher mathematics courses. One reason for this may be that most state and college requirements include two years of mathematics, which is typically first-year algebra and geometry. In the studies at Johns Hopkins University, Fox attempted to create accelerated mathematics classes which would be appealing to mathematically-talented girls. This was an all-girl high school mathematics class designed especially to eliminate some of the social problems within the co-ed classrooms. At first, the results appeared promising. More girls were willing to participate and fewer dropped out. However, by the time the girls reached college, they

were doing no better in their mathematics classes or taking no more mathematics classes than the control group which had been in the co-ed classroom (Kolata, 1980).

Because mathematics is necessary for occupations, mathematics becomes the filter which keeps those out who do not have a strong mathematical background. This is often a factor which keeps women from such professions as engineering, computer science, and business (Jones, 1984). Even those females who are exceptionally gifted in mathematics are less likely to pursue a career in mathematics than gifted males. Benbow (1988; c.f. Halpern, 1992) did follow up on tens of thousands of students who had been labeled as mathematically gifted. Of these, 42% of the males had chosen careers in mathematics and science as compared to 25% of the females.

The socialization theory is strongly supported with research by many people. The socialization theory is found not only in the mathematical field, but in a number of different areas including science. The idea of men being doctors and women being nurses or men being the "bread winners" and the women caring for the children have been popular view in this country for many years and such opinions are hard to overcome. Yet when effort is made to overcome negative socialization

factors, do girls do any better? When Johns Hopkins created an all-girls accelerated mathematics class the final results showed that a change in socialization had not changed mathematical ability or participation. Such results would imply socialization had little to do with mathematical ability, instead, genetics had created a limit. Maybe girls do need to accept their limits while attempting to do as well as they are biologically able.

Summary

Alan Feingold (1988) has been doing research on cognitive gender differences of high school students using the DAT (Differential Aptitude Tests) and the PSAT (Preliminary Scholastic Aptitude Tests). Between 1960 and 1983 boys have closed the gap on cognitive gender differences for verbal skills, while the mathematical gap, in favor of boys, has remained constant. Yet, Hyde and his colleagues (Hyde, Fennema, & Lamon, 1990) found cognitive gender differences in mathematics to be small. They found females to be slightly superior in computation, males to be slightly superior in problem solving, and no gender differences relating to understanding of concepts. The extent of gender differences varies depending on the tests used and the process of analysis.

Present research still supports the gender differences in

mathematics with reasons similar to those stated by Maccoby and Jacklin (1974). Some believe in the genetic theory while others believe in the socialization theory, but most researchers agree that a combination of nature and nurture is responsible. Sandra Scarr (1987) believes that genes and the environment are both critical to the developmental process with each having its individual role. Scarr described the idea of nature and nurture when she stated, "Genes determine much of human experience, but experiential opportunities are also necessary for development to occur. Individual differences can arise from restrictions in environmental opportunities to experience what the genotype would find compatible. With a rich array of opportunities, however, most differences among people arise from genetically determined differences in the experience to which they are attracted and which they evoke from their environments" (from Scarr, 1987, pg. 74).

While researchers search for the answer to the gender difference in mathematics, teachers have the present task of educating students, both male and female. When students enter a classroom, they bring with them a wide range of skills, prior knowledge, study skills, attitudes, and beliefs. These concepts not only effect the way students learn mathematics, but the way a teacher must teach as well. The Curriculum and Evaluation

Standards For School Mathematics (1989), as prepared by the National Council of Teachers of Mathematics, states that past social injustices in the school systems will no longer be tolerated. Because current statistics show that it is mostly white males who study advanced mathematics, women, as well as all minorities, need to be encouraged to pursue the mathematics field. Never before have females had as much reason to believe that they can pursue any career they choose, however, they need encouragement and support from both teachers and parents. Parents have to believe that mathematics is as important for their daughters as it is for their sons (Kreinberg & Stenmark, 1984). Teachers need to present material so it is understandable, applicable, and appealing to both males and females.

Strategies to Develop Mathematical Skills

Whether the mathematical difference between boys and girls is because of social or genetic factors, or some combination of both, remains a mystery. However, being aware of this difference is the first step towards understanding the situation. It has been discussed how the socialization of females has created negative attitudes towards mathematics. Females have been taught to be apprehensive about mathematics and to rely on the judgement of others, to express ideas

verbally, and they have been deprived of games, toys, and activities which stimulate visual-spatial skills. Socialization begins in the home when children are young. If socialization is responsible for the negative mathematical attitudes of females, then changes must first take place in the home. Too often parents believe their children's education should come from the school when they are capable of integrating basic concepts of learning into every day life. This is especially true with the mathematics field. Parents can begin stressing the importance of mathematics when children are very young with simple concepts such as the number of plates when setting the table and the dividing of food into equal parts. Simple mathematical concepts can also be found in time, money, and weight. Also, as children grow they should be encouraged to recognize how mathematics plays a role in different professions. It is also helpful for girls to see women in the nontraditional roles (Kreinberg & Stenmark, 1984).

To help ensure that girls' mathematical learning is progressing at an acceptable rate, Kreinberg and Stenmark (1984) presented a list of ideas to encourage parent interaction in children's mathematical learning at home. They encouraged parents to play mathematical games, to introduce their daughters to computers, and to encourage their children to play with